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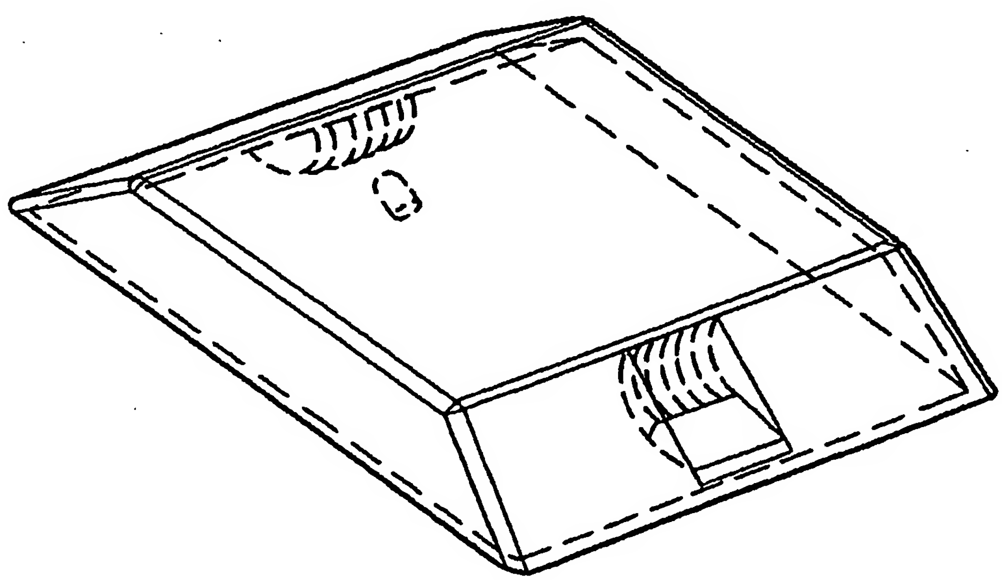

(57) Abstract

A pavement marker (10) that uses a focused LED (40) and/or tailored cube corner retroreflectors (44) to provide maximum illuminance to an oncoming vehicle. In particular, at closer distances of within about 200 feet (about 60.96 meters) the marker (10) provides substantially greater reflex in comparison to pavement markers using conventional cube corner or biconvex reflective elements; while at greater distances beyond about 200 feet (60.96 meters) from the marker (10), use of a focused LED (40) can provide brighter LED illuminance to the driver of an approaching vehicle than that afforded by conventional markers using a non-focused LED. The focused LED (40) can also increase the distance in which the marker (10) is visible thereby providing drivers earlier warning of road curvature.

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RETROREFLECTIVE PAVEMENT MARKER INCORPORATING A FOCUSED LED

Related Application

This application claims the benefit of United States Provisional Application Serial No. 60/130,068 filed April 19, 1999.

1. Field of the Invention

The present invention relates generally to reflective pavement markers incorporating at least one light-emitting diode, and, more particularly to pavement markers in which the intensity of emitted LED light and/or the intensity of reflected light can be substantially enhanced to improve the overall visibility of the marker to an approaching driver.

2. Background

Reflective pavement markers are well known in the art. They use well known retroreflection to reflect the headlights of an approaching vehicle so that the outlines of the lane being traveled by the vehicle are more readily discernable to the driver of that vehicle. Some raised pavement markers rely solely on retroreflection and cannot appear very bright at long distances because vehicle headlights cannot provide sufficient illumination at greater distances. A retroreflector's luminous intensity (candle power output) is equal to its specific intensity (for the observation angles, and so forth) corresponding to the particular distance multiplied by the headlight provided illuminance at that distance (and angle).

Self luminous pavement markers produce a certain candle power output practically independent of vehicle distance. There is only a slight dependence on the angle of view which generally changes slightly with distance.

There is generally increasing desire for pavement markers which incorporate both retroreflection and self-illumination. LEDs are today's preferred means of self-illumination for highway markers. Examples are PCT Application W087/02400, U.S. Patent No. 5,245,454, U.S. Patent No. 3,836,275, 3,164,071, and 5,074,706.

Commercial LEDs tend to produce light beams that are roughly rotationally symmetrical about their axis with considerable non-uniformity. As such, markers incorporating LED's with fairly broad beam angles are not bright enough for visibility at longer distances. On the other hand, markers incorporating LED's with very narrow beam angles are not bright enough for visibility obliquely as they present themselves on curved roads. Accordingly, there is a desire in the art to increase the brightness of LED markers over their entire range of applications and to thereby also increase that range.

In the U.S., retroreflective markers are presently specified according to their specific intensity ("SI") for 0.2°, corresponding to approximately 700 feet (213.4 meters) for a passenger car. That 700 foot (213.4 meter) performance is wasted when used in conjunction with an LED. At a distance of about 500 feet (152.4 meters), a single light-emitting diode (LED) powered by a small battery and employing simple beam-shaping optics

will appear brighter than the brightest retroreflective pavement marker illuminated by automobile low-beam headlights. On the other hand, at a distance of about 100 feet (30.48 meters), the LED will appear dimmer than almost any retroreflective pavement marker illuminated by automobile low-beam headlights and viewed from the vehicle driver's position.

In view of the foregoing, it is a general object of the present invention to provide an LED-equipped retroreflective marker having improved visibility over its entire range of visibility, and to extend the range of such visibility, by modifying the optical properties of both the retroreflective elements and the LED beam.

Another object of the present invention is to provide an LED-equipped pavement marker in which the LED beam is enhanced with beam-shaping optics to make it appear brighter to an oncoming vehicle.

Yet another object of the invention is to increase the intensity of retroreflected light for vehicles and their drivers closer to the pavement marker, for example in the distance range of within about 200 feet (60.96 meters).

These and other objects will become apparent hereinafter to a person skilled in the art.

SUMMARY OF THE INVENTION

The present invention is a reflective pavement marker comprising: at least one retroreflective area which reflects light originating from an approaching vehicle back to a driver of the vehicle; at least one light-emitting diode (LED) which emits a beam of light visible to the driver; and beam shaping optics capable of modifying the LED beam from an approximately circular beam shape to a substantially non-circular beam shape having a maximum height and a maximum width, such that the maximum width is greater than the maximum height. Preferably the width is at least 1.25 times the height, and most preferably at least about 1.5 times the height.

The invention is further directed to a pavement marker comprising at least one light-emitting diode (LED), and beam shaping optics capable of modifying the LED beam into a substantially non-circular beam shape having a maximum beam width and a maximum beam height, such that the maximum width is greater than the maximum height.

In a further embodiment the invention is a pavement marker comprising at least one light-emitting diode (LED), and beam-shaping optical means capable of modifying the LED beam from an approximately circular beam shape to a substantially rectangular beam shape. In this embodiment, the height and width of the beam may be roughly equivalent, the height may be greater than the width; or the width may be greater than the height.

In a preferred practice of each of the above aspects of the invention a retroreflective area of the marker will comprise cube corner or biconvex retroreflector elements having their reflex tailored for higher SI's (specific intensities) at observation angles greater than about 0.7°. These observation angles correspond to a viewing distance within about 200 feet (60.96 meters) from the marker. By tailoring or modifying the reflex of the corner cubes or biconvex elements for the aforementioned observation angularity (which can be done in a manner well-known in the art) the reflective area of the marker will appear much brighter within the distance range of about 200 feet (60.96 meters) as compared to conventional reflective pavement markers. In fact, in this distance range, a marker of the present invention can appear approximately twice as bright as a conventional reflective pavement marker.

The beam shaping optics used in the present invention preferably comprise a lens, and most preferably an anamorphic lens, to modify the native LED beam. As used in herein the term "anamorphic" is meant to denote optical means which change the angular shape of the beam produced by a native LED. For example, in the present invention anamorphic optics can be used to modify the native LED beam from a substantially circular shape to a substantially rectangular or elliptical form. While any anamorphic lens capable of achieving this result is contemplated for use in the invention, the types of anamorphic lenses which have been found most suitable are lens which have computer generated surfaces profiles that are tailored for the specific light output of a given LED. Such lenses have non-quadric, non toric computer

developed surfaces, and may be comprised of multiple segments.

An appropriate anamorphic lens surface profile may be generated in a well-known manner using computer assisted design software. As a result of the beam shaping optics, the rectangular (or elliptical) beam has a vertical angle of preferably within the range of about 7 to about 15 degrees and a horizontal angle in the range of about 20 to about 45 degrees. The use of beam shaping optics in accordance with the present invention can produce an approximate five-fold increase in the observed brightness of the LED at any given distance. Figure 27 represents a beam shape obtained using anamorphic optics designed specifically for the light output of a Nichia 510 white LED. Focused LED pavement markers in accordance with the present invention will preferably elicit LED beams which roughly approximate the beam shape depicted in Figure 27, regardless of the type of LED used. However, it should be understood that there is great variability in the light output of different commercially available LED's. Anamorphic optics tailored to produce a desired beam shaping for a given LED, will not necessarily (and most likely will not) result in the same beam shape when applied to a different LED.

The advantages of the invention include enhanced long distance visibility resulting from the focused LED beam, as well as brighter close range retroreflection resulting from corner cube or biconvex elements (e.g., microspheres) having modified observation angularity. Although the use of tailored reflector elements is an optional feature of the invention, combination thereof

with the focused LED beam provides the added benefit of shifting the reflex of the marker from a smaller observation angle, where it is not needed, to larger observation angles, corresponding to distances from the marker at which the reflex intensity is dominant over the LED intensity.

For purposes of the present invention the term "beam shape" is intended to denote the beam region within which the intensity of the beam is at least $1/e^2$ (13.5%) of the central beam intensity (where central beam intensity is understood as the average intensity over a central region of the beam subtending 3 degrees). The term "beam shape" intended to encompass both the shape and the size of the beam.

Other aspects of the invention include the following:

1. The LED can be buried in the marker with clear overlay for protection from snow plows.

2. The electronics may be encapsulated with the epoxy normally used for marker installation.

3. The signal can be concentrated at the top edge of the reflector where it can be seen at the greatest distance.

4. The LED can be positioned at the top edge of the reflector where the metal hood of the reflector (as defined in earlier art) will provide additional protection for it.

5. Because snowplowable castings already have so much surface area compared to sun country markers, there is sufficient space to place the LED.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is more fully understood when considered in conjunction with the following drawings and the Detailed Description which follows.

FIG. 1 is a perspective view of a sun country marker base of the present invention;

FIG. 2 is a top view of the base of the sun country marker illustrated in FIG. 1;

FIG. 3 is a cross-sectional view of the base of the novel marker of FIG. 2 taken along lines A-A;

FIG. 4 is an exploded view of a complete sun country type pavement marker with one LED;

FIG. 5 is a front view of the novel LED, circuitry to drive the LED, and the ambient light sensor for keeping the unit turned *off* during the daytime;

FIG. 6 is a side view of the lens unit and circuitry illustrated in FIG. 5;

FIG. 7 is a perspective view of the LED flashing unit of FIG. 5;

FIG. 8 is a top view of the LED flashing unit with the ambient light detector extending from the opposite side;

FIG. 9 is a perspective view of the back side of the retroreflector panel;

FIG. 10 is a front perspective view of the retroreflector panel of FIG. 9;

FIG. 11 is a back view of the retroreflector panel illustrated in perspective in FIG. 9;

FIG. 12 is a cross-sectional view of a sun country marker illustrating the fluorescent cover, the LED unit, and the retroreflector panels;

FIG. 13 is a side view in perspective illustrating one of the batteries that is located in the housing of the pavement marker;

FIG. 14 is a cross-sectional view taken from side-to-side of the marker illustrating the novel pavement marker of the present invention;

FIG. 15 is a perspective view taken from the front of a snow country marker that incorporates the novel LED and retroreflector panel;

FIG. 16 is a side perspective view of the novel snow country marker of FIG. 15; and

FIG. 17 is a front perspective top perspective of the snow country marker having the LED and retroreflector panel therein.

FIG. 18 is a graph approximating the typical cone of light from an LED and the modified angle of light from the LED for the present invention.

FIG. 19 is a graph illustrating the angle of light emitted by the retroreflectors of a typical retroreflector unit as compared with the reflected light from a modified retroreflector of the present invention, as observed by an approaching vehicle;

FIG. 20(a) graphs the LED luminous intensity of the marker of the present invention; the reflex luminous intensity thereof; and the total luminance at a varying distances.

FIG.20(b) is similar to the graph in FIG. 20(a) except that it graphs the illuminance received by a driver at varying distances from a pavement marker according to the present invention.

FIG. 21 is a front view of a schematic representation of a raised pavement marker having a retroreflective lens including an LED of the present invention;

FIG 21(a) is a schematic representation of a raised pavement marker having mounted therein a fresnel-type multi-segmented lens of the type.

Figure 21(b) represents a further view of the lens molded integrally as part of the marker cover.

FIG. 22 is an electrical circuit diagram of a flasher that can be used with the present invention.

FIG. 23 is a diagram of a test unit using a Fresnel lens to adjust the vertical angle of light emitted by the LED.

FIG. 24 is a front view of the testing device of FIG. 7.

FIGS. 25 and 26 are raytracings showing LED light being shaped by an anamorphic lens in accordance with the present invention.

FIG 27 is graph which depicts the beam shape of a focused LED according to the present invention.

DETAILED DESCRIPTION

As stated previously, pavement markers that rely solely on retroreflection cannot appear very bright at long distances because vehicle headlights cannot provide sufficient illumination at greater distances. Because the luminous intensity (candlepower output) of the retroreflector is equal to its specific intensity (for the observation angles) corresponding to a particular distance multiplied by the headlight-provided

illuminance at that distance (and angle), the luminous intensity diminishes significantly with distance.

On the other hand, self-luminous markers produce a certain candle power output which for all practical purposes is independent of distance. At a distance of 500 feet, a single light-emitting diode (LED) powered by a small battery and focused appropriately (for example, by employing the beam-shaping anamorphic optics in accordance with the present invention) will appear brighter than the brightest retroreflective pavement marker illuminated by automobile low beam headlights. On the other hand, at a distance of approximately 100 feet, the luminous intensity of any conventional reflective marker illuminated by automobile low beam headlights will be greater than the luminous intensity of the LED.

Incorporation of LED into a Pavement Marker

The pavement marker of the present invention can be a marker used in sun countries or a marker used in snow countries. It has a light-emitting diode (LED), at least one, used in conjunction with a panel of retroreflector lenses. The LED can be viewed in one or both directions. In like manner, the retroreflectors can be placed on either the forward or rear of the pavement marker so that it can reflect light in either one direction or both directions.

The LED's are driven by a battery that can be recharged by a solar element through the day and the battery used at night. It can be programmed such that two or more pavement markers flash in a predetermined

sequence or each one can be switched on or off as desired. Each marker can have a variable flashing rate and has an extended cover to protect the retroreflector panels with the cover being below the housing side edges so that the cover itself is protected from snowplow blades. The extended cover can be a fluorescent cover that fluoresces with different colors depending upon the material from which the fluorescent cover is made. The marker has recessed positions on each side so that it can be conveniently manually handled with two fingers. It can be permanently affixed to the roadway or can be portable.

The marker of the invention can be used in a kit with two or more units having prefixed flashing frequencies that can be controlled if desired by a radio receiver wherein the LED's can be caused to flash at a different frequency than the prefixed frequency flashing rate that is set at the factory. By combining several of the markers that flash at predetermined rates, a cohesive seal can be obtained from the plurality of markers.

In somewhat greater detail, FIG. 1 is an upper perspective view of a base of the novel pavement marker of the present invention illustrating the base 10 having a front side 12, a rear side 14, and battery recesses 16 and 18. It also has a recess 20 in which the electronic circuitry for the LED is located. A truncated cone-shaped area 22, taken in a plane view, is shown that is prepared for receiving an LED. A like area 24 is found on the rear side 14 of the pavement marker base 10. Front sloping surface 26 and rear sloping surface 28 receive retroreflective panels such as shown in FIGS. 9,

10, and 11. If the retroreflector device is to provide light in only one direction such as front side 12, then the rear sloping surface 28 may be used for a solar cell to charge the batteries that are located in recesses 16 and 18. Side recesses 30 and 32 provide finger holes to conveniently enable a user thereof to pick up the base 10. In addition, a passage 34 in recess 30 allows for a photodetector to be placed therein, as will be shown and discussed later, to measure ambient light for purposes of controlling the LED.

FIG. 2 is a top view of the base shown in FIG. 1 illustrating the various components thereof with like numerals as illustrated in FIG. 1.

FIG. 3 is a cross-sectional view of the base 10 shown in FIG. 2 taken along lines A-A showing the front and back sides 12 and 14, the recess 20 for the LED electronics, and the sloping sides of the truncated plane cone-shaped areas 22 and 24 for enabling light from the LED to be passed therethrough as will be shown later.

FIG. 4 is an exploded view of the entire sun country pavement marker of the present invention. It has, of course, base 10 having recesses 16 and 18 for batteries 40 and 38 and recessed area 20 for holding the electronic circuitry 42 associated with the LED. The retroreflective panel 44 is mounted on a sloping surface 26 while either a retroreflective panel 46 or a solar panel 46 is mounted in the recessed area 28 at the rear of the pavement marker 36 depending upon whether the battery will be recharged with a solar cell or the unit will provide two-way light transmission. A cover 48

seals the unit together. Cover 48 may be a translucent panel or a fluorescent panel enabling light entering therein to appear at the front edges 49 as illustrated in FIGS. 12 and 13.

FIG. 5 is a front view of the electronic circuitry 42 for the LED. As can be seen in FIG. 5, an LED 50 is controlled by circuitry 54. The LED is preferably a white Nichia NSPW510BS. The driving current is preferably 6 ma. The forward voltage for this LED is approximately 3.3 v. Circuitry 56 is coupled to an ambient light photodetector 58 to turn the LED *off* during the daylight hours and *on* from dusk to dawn. Circuitry 52 may be a radio receiver that can receive signals to change the programming of the LED 50 such that it will flash in any predetermined fashion. Pins 60 can be used to couple an external switch for activating and deactivating the unit memory. This feature is particularly helpful prior to the installation of the pavement marker where it can be turned *off* prior to installation but activated at the time of installation.

FIG. 6 is a side view of the LED and associated circuitry 42 shown in FIG. 5. It will be noted that the photodetector 58 is facing out of the page in FIG. 6; whereas in FIG. 8, it is pointed in the opposite direction illustrating that units can be made with the photodetector unit 58 mounted in either direction perpendicular to the axis of the LED 50. The circuitry 56 is coupled to the photodetector 58 through leads 57 to service a switch to turn *off* the LED during the daylight hours from dawn to dusk and to activate the unit from dusk to dawn. Circuitry 54 contains the flashing

circuitry that is activated when the switching circuitry 56 receives a signal from the photodetector 58. Circuitry 54 can have any conventional type of circuitry for flashing the LED 50. The flashing rate can be at any desired interval. However, a radio RF receiver 52 can be used to receive signals from a remote source so as to change the programming of the LED 50 flashing rate.

FIG. 6 is a side view of the LED 50 and its associated circuitry collectively identified by the numeral 42.

FIG. 7 is a perspective view of the LED and associated circuitry 42 shown in FIG. 5.

FIG. 8 is the same circuitry shown in FIGS. 5, 6, and 7 except that the photodetector 58 points in the opposite direction illustrating that the ambient light detector can be placed on either side of and perpendicular to the axis of the LED 50.

FIG. 9 is a rear perspective view of the retroreflective panel 60. It has retroreflectors 62 and a center portion that has a focusing lens 64 for the LED.

FIG. 10 is a front perspective view of the panel 60.

FIG. 11 is a rear plan view of the retroreflective panel 60 illustrating the retroreflectors and the focusing lens 64.

FIG. 12 is a cross-sectional view of the sun country marker 36 illustrating the base 10, the fluorescent cover 48 having a front edge 49 which provides the fluorescent light toward an oncoming vehicle, the LED 50, the front electroluminescent panel 60, and the back electroluminescent panel 62 if the unit is to be a two-way retroreflector; whereas panel 62 may be a solar cell in the event that the pavement marker 36 provides light only in the forward direction.

FIG. 13 is a cross-sectional view taken lengthwise through the reflector from the front to the rear thereof through one of the batteries. It illustrates base 10, fluorescent panel 48 with its front edge 49, retroreflective panels 60 on the front and rear of the pavement marker having the retroreflectors 62 thereon. One of the batteries 38 is shown in cross section.

FIG. 14 is a lateral cross-sectional view of the pavement marker 36 of FIG. 12 illustrating the base 10, the fluorescent 48, the batteries 38 and 40, the LED 50 and its associated circuitry 54 and 56 and also illustrates the RF circuitry 52. The phototransistor 58 is shown coupled by leads 57 to circuitry 56. The side recesses 30 and 32 to provide finger holes for the pavement marker are also shown.

It will be noted in FIGS. 12 and 13 that the front edge 49 of fluorescent panel 48 extends slightly beyond the retroreflector panel 60. This construction provides a protection to the retroreflective unit 60 from external forces such as a vehicle tire. Because the unit

is small, retroreflective panel 60 receives protection by its being inset below the leading edge 49 of the fluorescent panel 48 and the leading edge 11 of base 10.

Because the RF radio signal receiving unit 52 can be contacted remotely with RF signals, it causes the programming in the circuitry 54 for the LED to be reprogrammed to flash at any desired rate. Further, if a number of the pavement markers are used as a team or kit, they can be placed advantageously and then programmed with RF signals to cause them to flash in some predetermined pattern or rate. Thus, for example, for use in times of emergency along highways, airport runways, and the like to accommodate situations where a peculiar or particular light pattern is required.

FIG. 15 is an upper right front perspective view of a snow country version of the present inventive retroreflector unit and LED. As can be seen in FIG. 15, the unit 64 has a base 65 of general well-known design to allow it to be recessed into the roadway. However, it has a central recessed portion that receives the retroreflector panel 66 having the LED such that retroreflective panel 66 is protected from snowplows that pass over the top thereof.

FIG. 16 is an upper side perspective view of the snowplow version of the pavement marker 64 shown in FIG. 15. Again, the base 65 can be seen to have a recess below the outer shoulders in which recess the retroreflector and LED panel 66 is located. A solar panel 68 may also be placed in the recessed area in the

center of the pavement marker 64 to provide charging of the batteries for the pavement marker as explained earlier with respect to the sun country version.

Again, in FIG. 17, a front perspective view of the pavement marker 64 illustrates the base 65, the retroreflective panel 66 which includes an LED, and the solar panel 68.

Thus, there has been disclosed a novel pavement marker having sun country versions and snow country versions. The pavement marker includes forward and, if desired, rearward facing sloping retroreflector panels. The retroreflector panel has in the center portion thereof a transparent area behind which is placed a focusing lens which receives the light from the LED and focuses it appropriately to provide proper distance sighting of the LED. It also has a fluorescent cover that receives light from the LED and focuses that light along the leading edge of the fluorescent cover to provide a visible lighted area in color, depending upon the color of the fluorescent panel. The fluorescent panel extends forwardly coextensive with the height of the side walls of the base but extending forwardly of the retroreflective lens so as to protect it from external sources such a vehicle tire.

The novel pavement marker also has on each side thereof a finger position in the form of a recessed area that allows the pavement marker to be picked up with the use of two fingers.

Finally, a light sensor is placed on the side of the pavement marker to serve as an ambient light detector. Thus, during the daytime the photodetector provides a sufficient output signal to bias the LED circuit in the *off* position. However, in the dusk to predawn hours, insufficient light is received by the photodetector cell to turn *off* the LED unit and thus it provides a source of light automatically from dusk to dawn. A solar panel is provided either in one of the locations for a retroreflective panel so as to recharge the battery. Of course, the solar panel could also be a portion of the fluorescent cover to receive light during the daylight hours to maintain a sufficient charge on the battery so that they can be operated throughout the night.

LED Focusing

For highway marking applications, the beam of light produced by an LED has roughly a circular shape. FIG. 18 schematically illustrates an LED light source at 10 that is generating a cone-like volume of light 12 (illustrating a vertical angle α thereof.) If the eye level of a vehicle is at 14, it can be seen that most of the vertical angle α of light 12 is above eye-level. Because the LED 10 is unnecessary at distances less than about 200 feet, where the retroreflector is dominant, the LED 10 need only cover a vertical angle of approximately 3° from the horizontal to the height of a driver's eye at 200 feet.

According to the present invention, the LED beam is preferably shaped into an approximately rectangular or elliptical form using suitable beam

shaping optics, preferably comprising anamorphic optics, to focus the native LED light. Preferably, the resultant rectangular or elliptical LED beam extends about 7° to about 15° vertically and about 20° to 45° horizontally. For example, the optics-shaped beam depicted in Figure 27 provides its design specified intensity (see Table 1, below) within a range of about 12° vertically and about 40° horizontally. Depending upon the choice of LED, the beam shaping optics of the present invention can produce up to a five-fold increase in the observed brightness of the LED.

The ability to focus the light emitted by the LED using, for example, an anamorphic lens, was verified with a fresnel cylinder lens of focal length 100 mm located approximately 100 mm from the LED, thus allowing "tuning" of the vertical angle. See FIGS. 23 and 24 for a general illustration of a device used for verifying the concept. In FIG. 23, a raised pavement marker 28 with an LED 34 is placed on a holder 30 with a Fresnel lens 32 held 100 mm from the LED 34 on marker 28. By adjusting the Fresnel lens 32 vertically, the angle of light from the LED 34 was adjusted in the vertical plane. FIG. 24 illustrates a front view of the device of FIG. 23. In commercial practice, the pavement marker may be of a type sold by Stimsonite Corporation as its Model 88 or 944. Examples of suitable markers are fully disclosed in commonly assigned U.S. Patents 3,332,327; 5,277,513; 3,392,639; 3,485,148; 3,587,416; 3,790,293; 3,809,487; 3,833,285; 3,873,184; 4,227,772; 4,854,768; 5,403,115; and 5,425,696; all of the foregoing being incorporated by reference in their entirety.

The use of anamorphic optics shapes the native LED beam, and depending upon the light output of the native LED to which the optics are applied, can increase the uniformity and brightness of the LED beam over its entire visible range. This is important not only in straight road applications but also in curved road applications where oblique visibility of the marker is important for safety.

The beam shaping optics can be a lens attached to the LED, or attached to or integrally formed with a housing or cover of the marker positioned in proximity to the LED (see figure 21(a) and 21(b)). The anamorphic lens can be attached to the LED or the housing next to the LED, in any well known manner such as by gluing. High clarity polymeric materials may be used to form the lens element, such as polycarbonate or polyethylene terephthalate.

In a preferred embodiment, the desired lens may be molded as part of the shell forming the marker housing.

In a commercial unit, the optics will be miniaturized. In one version, an anamorphic lens having a non-quadric, non toric computer developed surface glued directly onto the LED to form the most compact design. In another embodiment, a two-element design providing at least three refracting surfaces is preferred to obtain a more unified beam. However, beam uniformity is not necessarily desirable. For example, horizontal uniformity presumes that every horizontal entrance angle up to the limit is equally important. Yet from a purely

utilitarian and safety standpoint, a central weighted beam is preferable. The specifications set forth in Table 1 exemplify a centrally weighted beam according to the present invention. Some vertical non-uniformity is desirable. In the present design, the vertical distribution from the LED will depend on (1) the anticipated contribution of the retroreflector, and (2) desired fall-off of brightness with distance. Thus, as can be seen in FIG. 20, both the retroreflector and the LED contribute light at 200 feet. Both contribute light to the viewer between certain distances, for example, between about 300 feet and about 100 feet.

In a particularly preferred embodiment of the present invention, wherein a pavement marker uses both LED light and retroreflectance, LED focusing is combined with tailored retroreflectance in such a manner that (1) cube corner retroreflectors are tailored to provide dominant retroreflected light to a vehicle in a first distance between the marker and an oncoming vehicle; and (2) an LED provides dominant emitted light to the oncoming vehicle at a second predetermined distance between the marker and the vehicle. The second distance is preferably greater than the first distance. The term "dominant" denotes that light emitted by the LED appears more intense to the driver of a vehicle approaching the marker in the second predetermined distance range; whereas the reflex appears more intense than the LED light in the first distance range. In a particularly preferred embodiment, the first distance range is within about 200 feet from the marker, and the second distance is greater than about 200 feet from the marker. It is particularly preferred that the distance range for

observing the reflex light from the marker be in the range of about 50 feet to about 200 feet from the marker.

LED beam-shaping optics and/or modification of the marker's reflex preferably results in a marker in which the LED may be caused to appear brighter than the retroreflective light from a typical retroreflector at a distance of, for example, about 500 feet from the source. Moeover, the beam shaping optics is capable of causing the LED beam to appear brighter, to a driver making an essentially straightline approach to said marker from a distance therefrom of about 500 feet (152.4 meters), than the beam would otherwise appear in the absence of said beam-shaping optics.

Presently in the U.S., retroreflective markers are specified according to their SI for 0.2 °corresponding to approximately 700 feet (213.4 meters) for a passenger car. This is shown by lines 22 and 22(a) in FIG. 19 depicting the retroreflective light from a cube-corner or biconvex type retroreflector 20. Clearly, the 700 foot performance is wasted when used in the conventional manner with an LED. Therefore, in the present invention, the reflex of the corner cube or biconvex retoreflectors are preferably designed, in a well known manner, for SI's in the observation angle range of greater than about 0.7° as illustrated by line 18 and 18(a) in FIG. 19. Observation angles greater than about 0.7° correspond approximately to the distance within about 200 feet from the marker. The modified retroreflectors will look approximately twice as bright at that distance range as a typical reflective marker. Tailoring of the retroreflective cubes to provide observation angles in

the above-mentioned range may be accomplished in a known manner such as described in Heenan U.S. Patent 3,833,285, which is incorporated herein by reference.

It is preferred that the luminous intensity of the retroreflector be dominant within about 200 feet from the marker and that the luminous intensity of the LED be dominant beyond about 200 feet, (for example at 500 feet) as generally illustrated in Figure 20. The beam shaping optics can be used to make the LED appear brighter at a distance of 200 feet than it would otherwise appear without such beam shaping optics.

As shown schematically in FIG. 21, the body portion 36 of the marker will contain cube corner reflectors in area 38 that preferably have a reflex design for SIs observation angles greater than about 0.7, that corresponds to the distance range within about 200 feet of the marker. The LED 40 is located preferably near the top of the body portion that rests on base 33 in a well-known manner and has beam-shaping optics 42 such as an anamorphic lens glued directly onto the LED, or molded integrally with the cover of the marker, to change the vertical angle from the horizontal to the height of a car or truck driver's eye at approximately 200 feet. Thus, as an example, stated earlier, allowing for a ±2° marker vertical mounting misalignment, the LED 40 still needs to cover only about 7 degrees vertically.

<u>Lens Design Parameters</u>

A fresnel type lens having five segments was designed to meet the output pattern specified in Table 1, below using a Nichia 510 white light LED. The lens design was accomplished using raytracing software in conjunction with a spatial characterization of the LED output. Best fit surfaces were calculated using two dimensional software calculation techniques. Errors resulting from the two dimensional calculation were fed back into pattern requirements until suitable surface approximations were reached. Output distributions were analyzed for minimum LED current and positioning sensitivity.

TABLE 1

	Design Intensity Requirements (Candellas)								
Horiz/Vert	-20	-15	-10	-5	0	5	10	15	20
7.5	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
4.5	0.24	0.24	0.24	0.6	0.6	0.6	0.24	0.24	0.24
1.5	0.24	0.24	0.24	0.6	0.6	0.6	0.24	0.24	0.24
-1.5	0.24	0.24	0.24	0.6	0.6	0.6	0.24	0.24	0.24
-4.5	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24

Figure 27 represents the optics-shaped beam output using a Nichia white 510 LED operating at the

manufacturer's minimum specified output for 7.4 mA average current.

In order to maximize ground clearance, the lens was designed such that light energy distributed to the top of the output pattern is emitted from the bottom of the lens and light angled to the bottom of the pattern emits from the upper portion of the lens. This effect can be seen in the following side view of the raytrace shown in Figure 26.

An amber HLMP DL31 was placed behind the lens developed for the Nichia lens at several positions; however, the resulting pattern was very different from that of Figure 27 due to the narrower output of the HLMP-DL31 LED and the different energy distribution of the LED; thus indicating the importance of designing each lens for the specific light output of a particular LED.

Figure 21(a) is a solid model of the lens as placed inside the road marker body of the present invention. The marker is 4x4 inches across the bottom and is 0.75 inches thick with a face angle of 40 degrees from horizontal.

Figure 27 illustrates that a computer generated lens (depicted in figure 21(b)) produces an acceptable output pattern for the Nichia 510 white LED with good energy distribution and efficiency capable of meeting the specifications set forth in Table 1.

WHAT IS CLAIMED IS:

1. A reflective pavement marker comprising:

at least one retroreflective area which reflects light originating from an approaching vehicle back to a driver of the vehicle;

at least one light-emitting diode (LED) which emits a beam of light visible to the driver; and

beam shaping optics capable of modifying the LED beam from an approximately circular beam shape to a substantially non-circular beam shape having a maximum height and a maximum width, such that the maximum width is greater than the maximum height.

2. The reflective pavement marker of claim 1 wherein the maximum width is at least about 1.25 times the maximum height.

3. The pavement marker of claim 1 wherein the maximum width is at least about 1.5 times the maximum height.

4. The pavement marker of claim 3 wherein the modified beam has a substantially rectangular shape.

5. The pavement marker of claim 4 wherein said substantially rectangular beam shape extends about 7 to about 15 degree vertically, and about 20 to about 45 degree horizontally.

6. The pavement marker of claim 5 wherein said substantially rectangular beam shape corresponds approximately to the beam shape depicted in Figure 28.

brighter than the LED light within most of the first distance range.

15. The pavement marker of claim 11 wherein, in a second distance range from the marker different from said first distance range, the LED beam appears brighter to the driver than the retroreflected light and said second distance range is greater than the first distance range.

16. The pavement marker of claim 1 wherein said beam shaping optics comprise an anamorphic lens capable of causing the LED beam to appear brighter to the driver than the beam would otherwise appear in the absence of the beam-shaping optics.

17. The pavement marker of claim 16 wherein said driver is one that is approaching the marker on a roadway in an essentially straight line path between the marker and the driver.

18. The pavement marker of claim 16 wherein siad driver is is one that is approaching the marker on a roadway along a curved path between the marker and the driver.

19. The pavement marker of claim 16 wherein said beam shaping optics is capable of causing the LED beam to appear brighter, to a driver making an essentially straightline approach to said marker from a distance therefrom of about 500 feet (152.4 meters), than such beam would otherwise appear in the absence of said beam-shaping optics.

7. the pavement marker of claim 5 wherein said beam shaping optics comprise an anamorphic lens.

8. The pavement marker of claim 3 wherein the modified beam has a substantially elliptical shape.

9. The pavement marker of claim 8 wherein the said substantially elliptical beam shape extends about 7 to about 15 degree vertically, and about 20 to about 45 degree horizontally.

10. The pavement marker of claim 9 wherein the beam shaping optics comprise an anamorphic lens.

11. The pavement marker of claim 1 wherein substantially all of the observed retroreflected light occurs in a first distance range within about 200' (about 60.96 meters) from the marker.

12. The pavement marker of claim 11 wherein said first distance range is from about 50 feet (15.24 meters) to about 200 feet (about 60.96 meters) from the marker.

13. The pavement marker of claim 11 wherein the retroreflective area comprises cube-corner or biconvex reflective elements having their reflex designed for higher specific intensities in the observation angle range of greater than about 0.7°, corresponding approximately to said first distance range.

14. The pavement marker of claim 11 wherein the retroreflected light appears to the driver to be

20. The pavement marker of claim 17 wherein the beam shaping optics are capable of causing the LED beam to appear brighter than said retroreflected light, at distance from the marker of about 500 feet (152.4 meters), to a said driver making an essentially straightline approach to the marker from said distance.

21. The pavement marker of claim 1 further comprising a flashing circuit for causing the LED to flash on and off on a periodic basis.

22. The pavement marker of claim 1 wherein the beam-shaping optics comprises an anamorphic lens.

23. The pavement marker of claim 22 wherein the LED is selected from the group consisting of a Nichia 510 white LED and an HLMP DL31 amber LED.

24. The pavement marker of claim 22 wherein the lens is attached to the LED.

25. The pavement marker of claim 24 wherein the lens is attached to a housing or cover of the marker.

26. The pavement marker of claim 25 wherein the lens is integrally formed or molded as a part of said housing or cover.

27. The pavement marker of claim 22 wherein said beam-shaping optics comprises more than one element and comprises at least three refracting surfaces.

28. The pavement marker of claim 22 wherein said beam-shaping optics comprises a fresnel lens.

29. The pavement marker of claim 28 wherein the fresnel lens comprises a plurality of segments

30. The pavement marker of claim 1 wherein the LED is a nichia white LED model number 501 and said beam shape corresponds approximately to that depicted in Figure 28.

31. The pavement marker of claim 1 wherein the LED is an HLMP DL 31 amber LED and said beam shape corresponds approximately to that depicted in Figure 28.

32. The pavement marker of claim 30 wherein the design specifications for the beam shaping optical means are as substantially set forth in the Table 1 of the specification.

33. A pavement marker comprising at least one light-emitting diode (LED), and beam shaping optics capable of modifying the LED beam into a substantially non-circular beam shape having a maximum beam width and a maximum beam height, such that the maximum width is greater than the maximum height.

34. The pavement marker of claim 33 wherein the maximum width is at least about 1.25 times the maximum height.

35. The pavement marker of claim 33 wherein the maximum width is at least about 1.5 times the maximum height.

36. The pavement marker of claim 35 wherein the beam shaping optical means comprises an anamorphic lens, and the modified beam has a substantially rectangular shape.

37. The pavement marker of claim 36 wherein said substantially rectangular beam shape extends about 7 to about 15 degrees vertically, and about 20 to about 45 degrees horizontally.

38. The pavement marker of claim 37 wherein said rectangular beam extends about 12 degrees vertically and about 40 degrees horizontally.

39. The pavement marker of claim 38 wherein said substantially rectangular beam shape corresponds approximately to the shape depicted in Figure 28

40. The pavement marker of claim 39 wherein the LED is a Nichia 510 white LED or an HLMP DL31 amber LED.

41. The pavement marker of claim 40 wherein the LED is a Nichia 510 white LED and the design specifications for the anamorphic lens substantially meet the design specifications in Table 1 of the specification.

42. The pavement marker of claim 35 wherein the beam shaping optical means comprises an anamorphic lens, and the modified beam has a substantially elliptical shape extending about 7 to about 15 degrees vertically, and about 20 to about 45 degrees horizontally.

43. The pavement marker of claim 33 wherein the beam-shaping optical means comprises a lens.

44. The pavement marker of claim 23 wherein the lens is an anamorphic lens.

45. The pavement marker of claim 44 wherein the lens is a fresnel lens.

46. The pavement marker of claim 44 in which the anamorphic lens comprises a plurality of elements providing at least three refracting surfaces.

47. The pavement marker of claim 33 in which the LED is driven by a battery at night, said marker further comprising a solar panel which recharges the battery during daylight hours.

48. The pavement marker of claim 33 comprising a cover which is recessed below side edges of the marker so as to protect the retroreflective area from snowplow blades.

49. The pavement marker of claim 33 comprising a fluorescent cover.

50. The pavement marker of claim 33 viewable from two directions.

51. The pavement marker of claim 33 wherein the LED flashing frequency is controlled by a radio receiver in the marker by a remote radio frequency source.

52. The pavement marker of claim 33 wherein the LED is turned off prior to installation in a roadway, and turned on after installation using a remote radio frequency source capable of communicating with a radio receiver present in the marker.

53. The pavement marker of claim 33 further comprising an ambient light photodetector to turn the LED off during daylight hours, and on from dusk to dawn.

54. The pavement marker of claim 33 comprising programmed circuitry which enables the marker to be activated by remote RF frequency to flash at a predetermined pattern or rate.

55. The pavement marker of claim 33 wherein the marker is adapted for sun country applications.

56. The pavement marker of claim 33 wherein the marker is adapted for snow country applications.

57. The pavement marker of claim 33 wherein the marker on each side thereof has a finger position in the form of a recessed area allowing the marker to be picked up with two fingers.

58. A pavement marker comprising at least one light-emitting diode (LED), and beam-shaping optical means capable of modifying the LED beam from an approximately circular beam shape to a substantially rectangular beam shape.

59. The pavement marker of claim 58 wherein the beam shaping optical means comprises an anamorphic lens.

60. The pavement marker of claim of claim 59 wherein the anamorphic lens comprises a fresnel lens.

61. The pavement marker of claim 58 wherein said rectangular beam shape has roughly the same height and width.

62. The pavement marker of claim 59 wherein said anamorphic lens is capable of making the LED beam appear brighter to the driver than said LED beam in the absence of the beam shaping optics.

63. The pavement marker of claim 59 wherein said rectangular beam has height greater than width.

64. The pavement marker of claim 58 wherein said anamorphic lens is capable of making the LED beam appear brighter to the driver than said LED beam in the absence of the beam shaping optics.

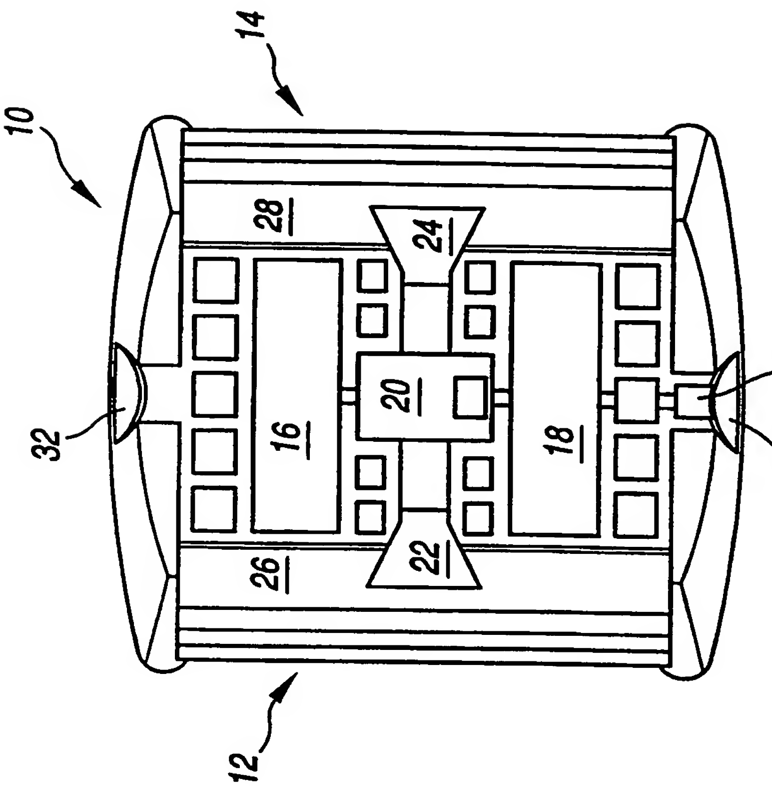

FIG. 2

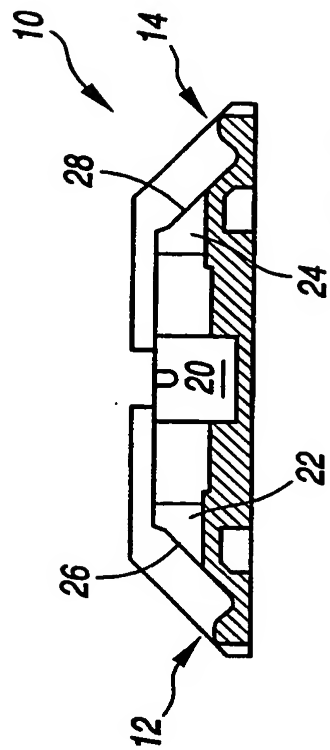

FIG. 3

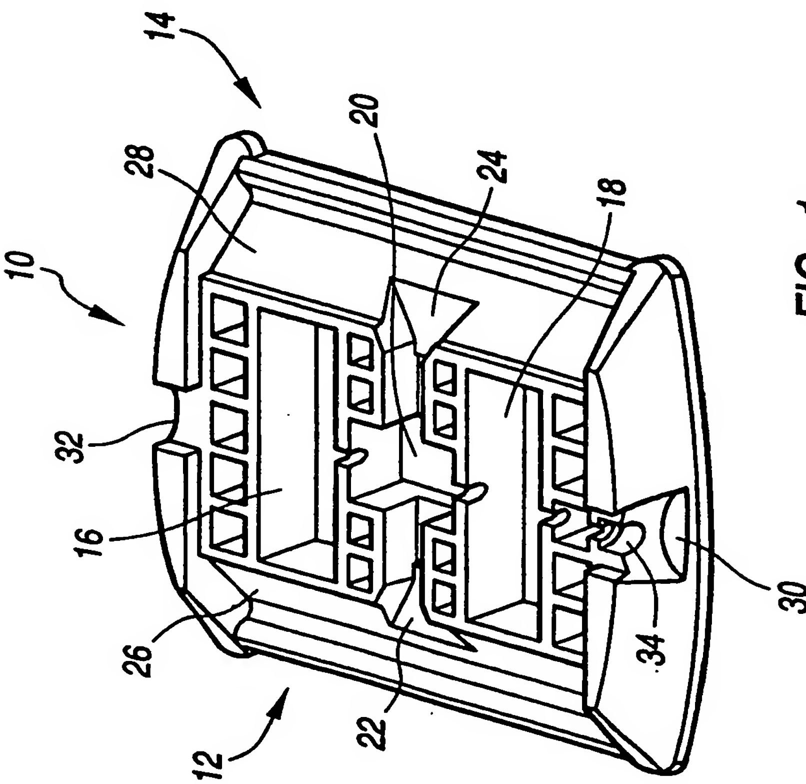

FIG. 1

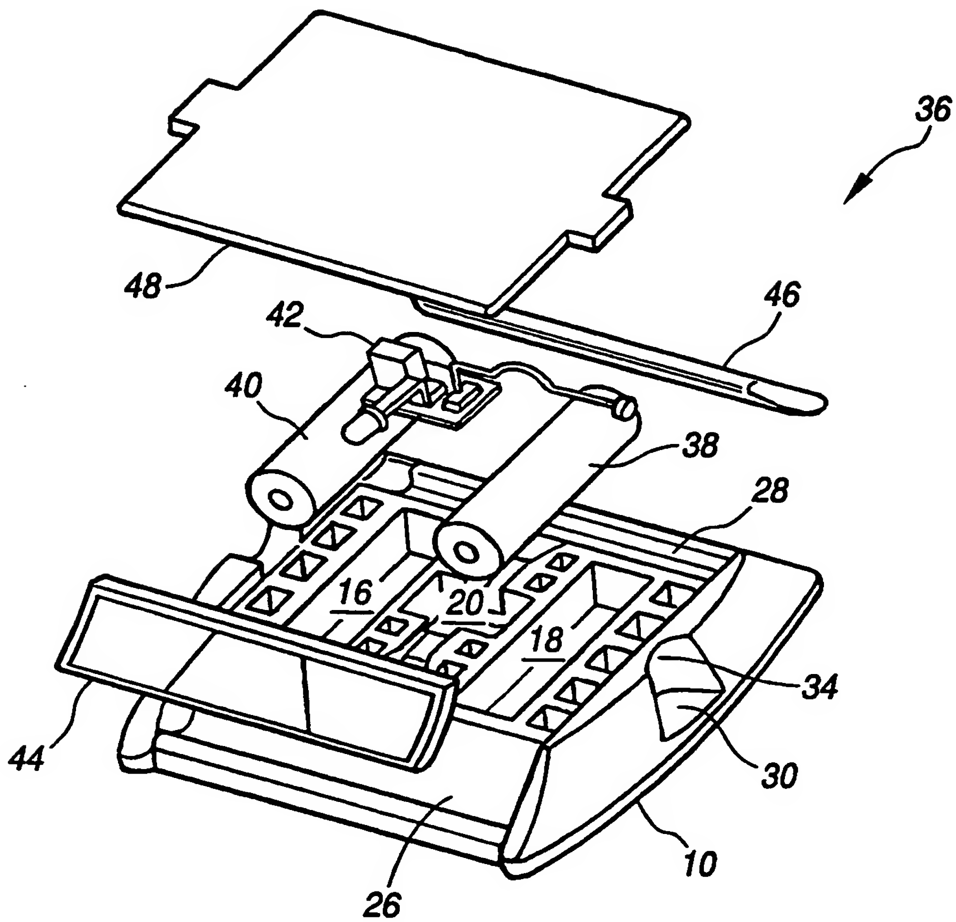

FIG. 4

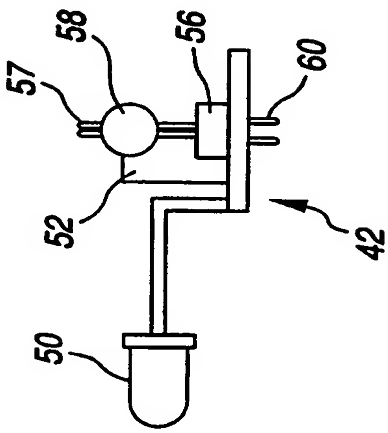

FIG. 6

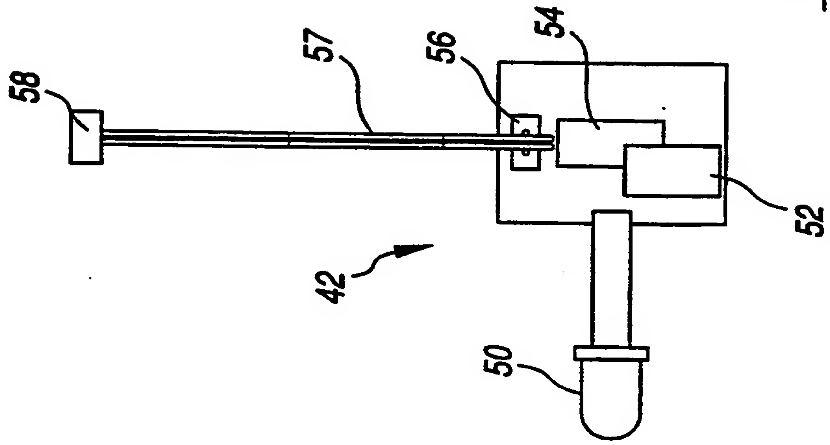

FIG. 8

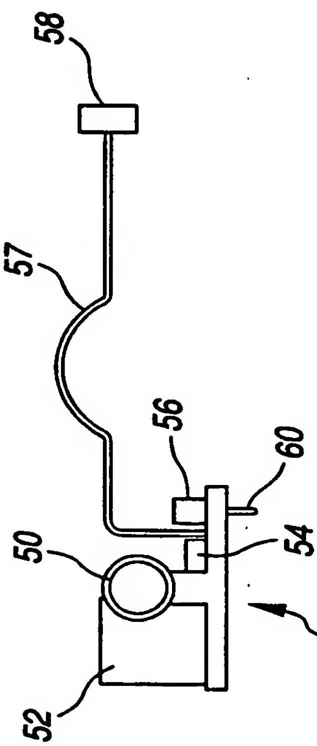

FIG. 5

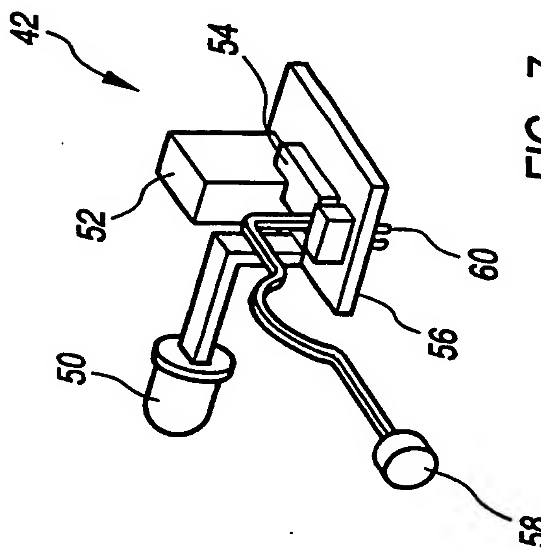

FIG. 7

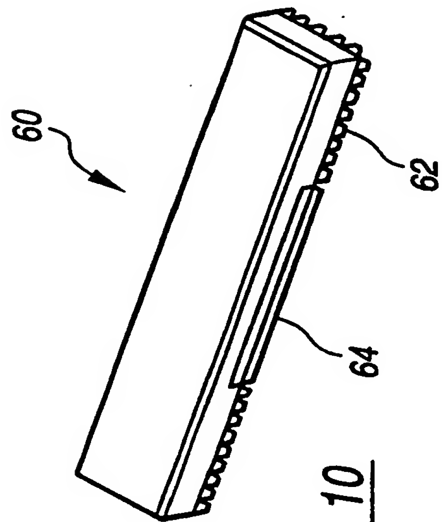

FIG. 10

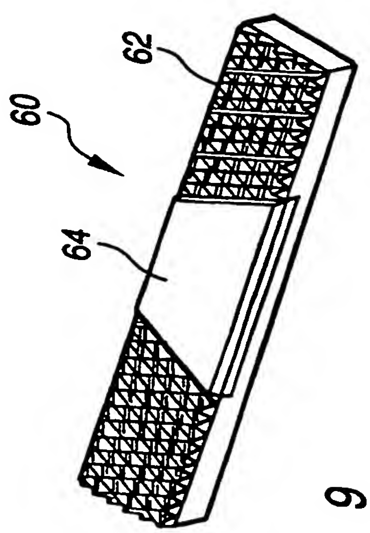

FIG. 9

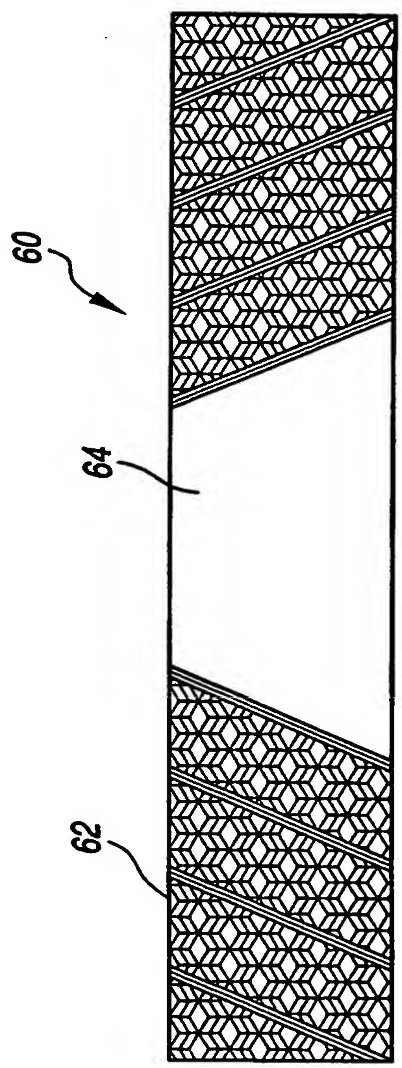

FIG. 11

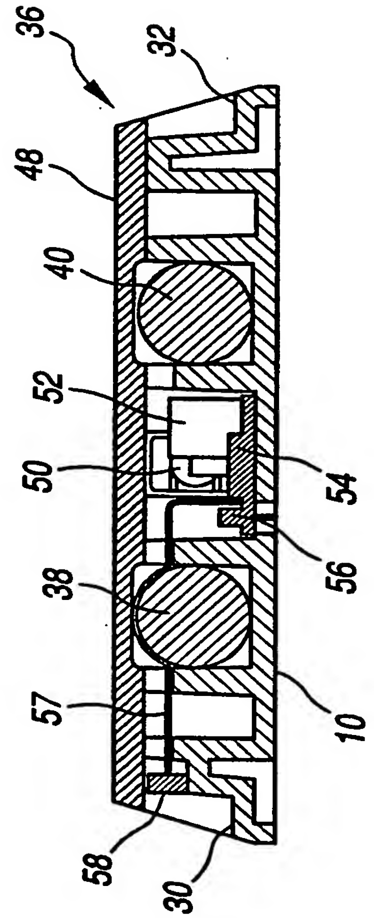

FIG. 14

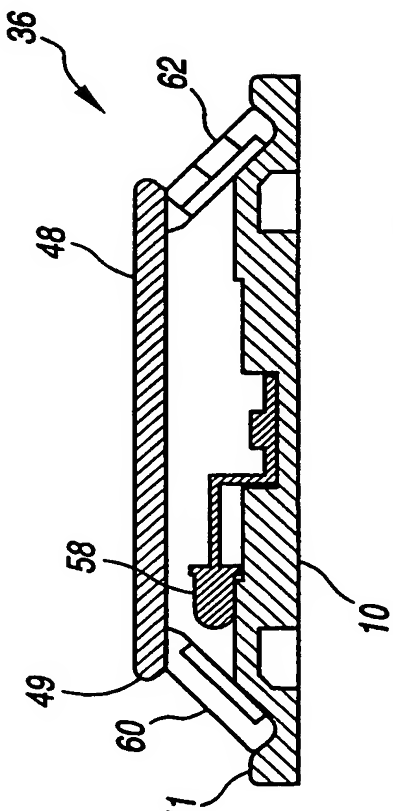

FIG. 12

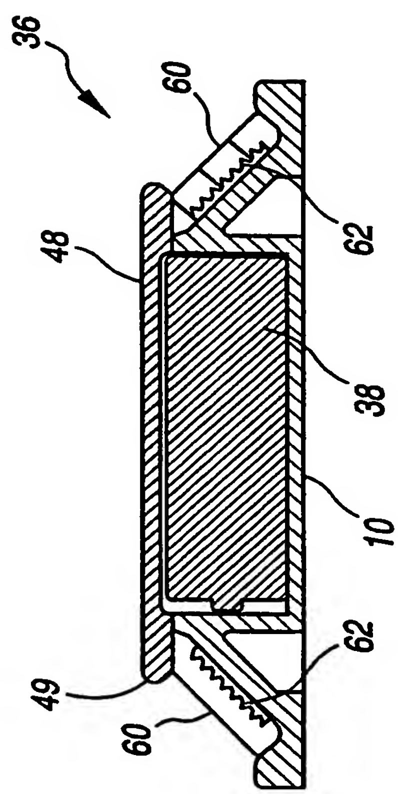

FIG. 13

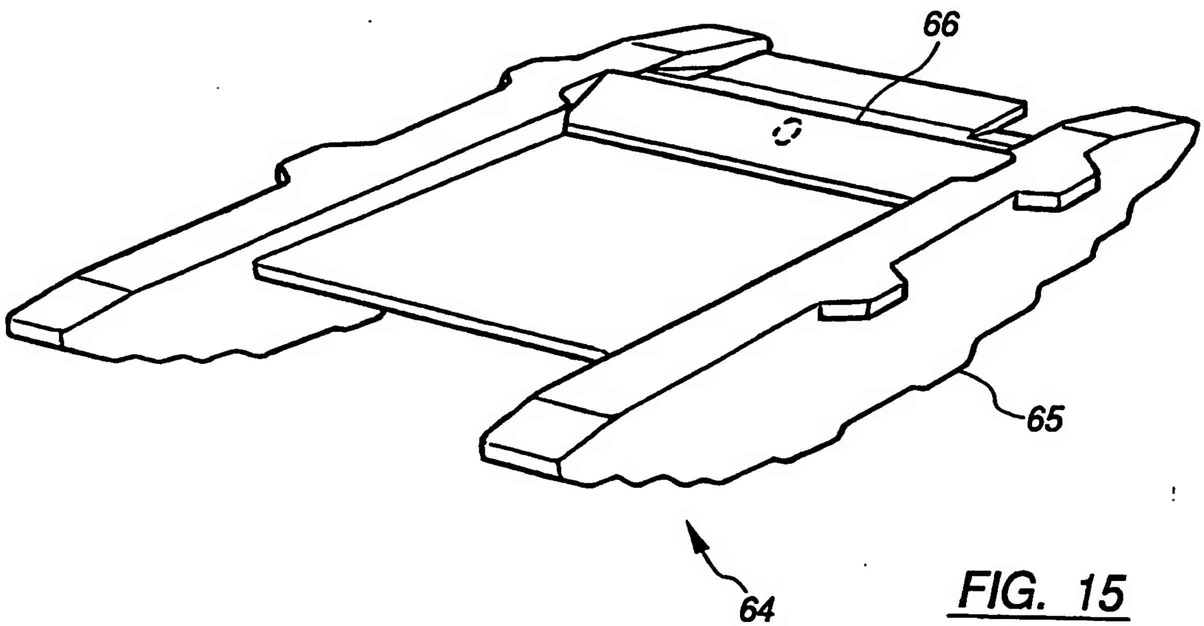

FIG. 15

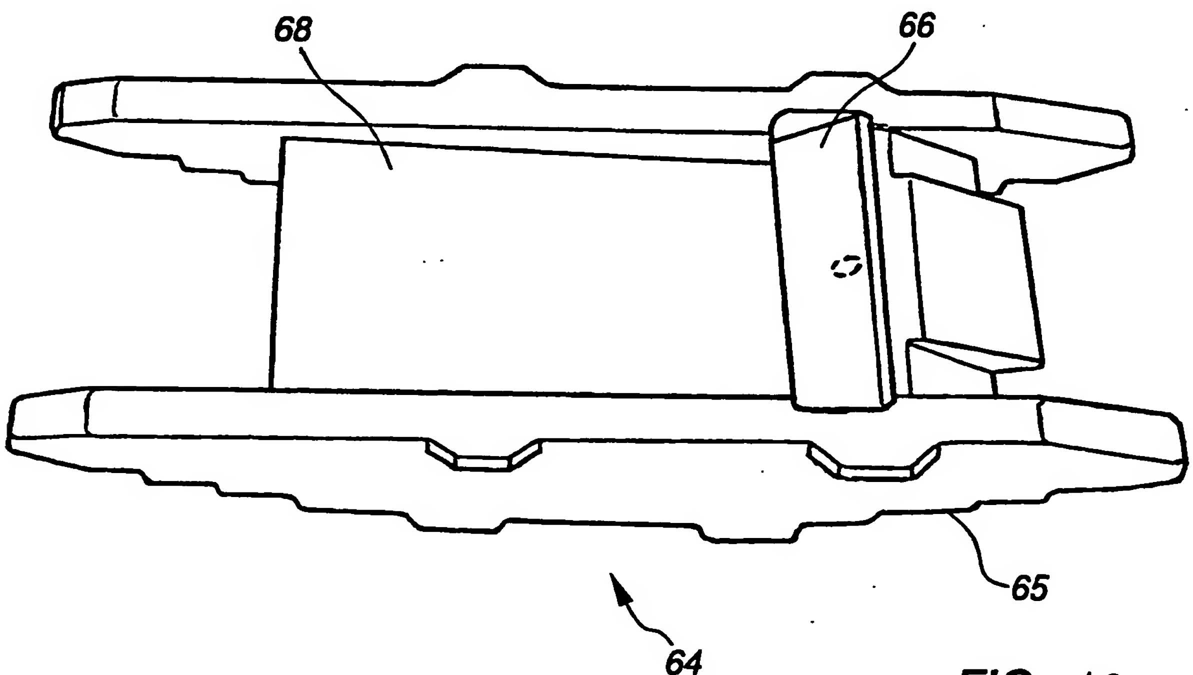

FIG. 16

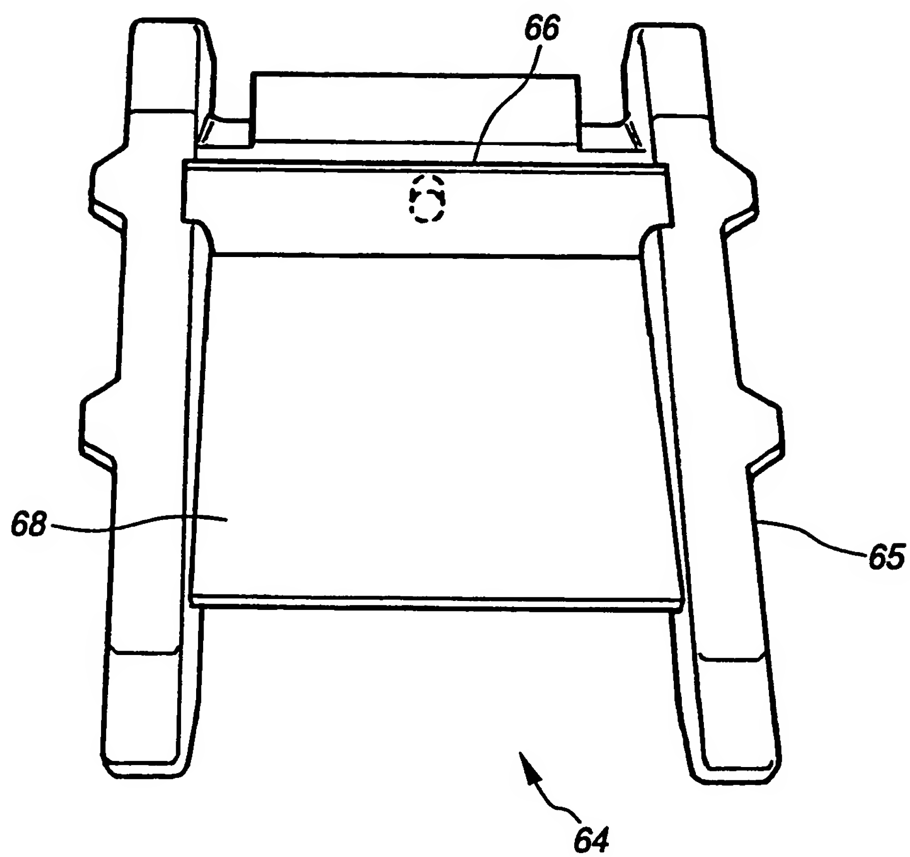

FIG. 17

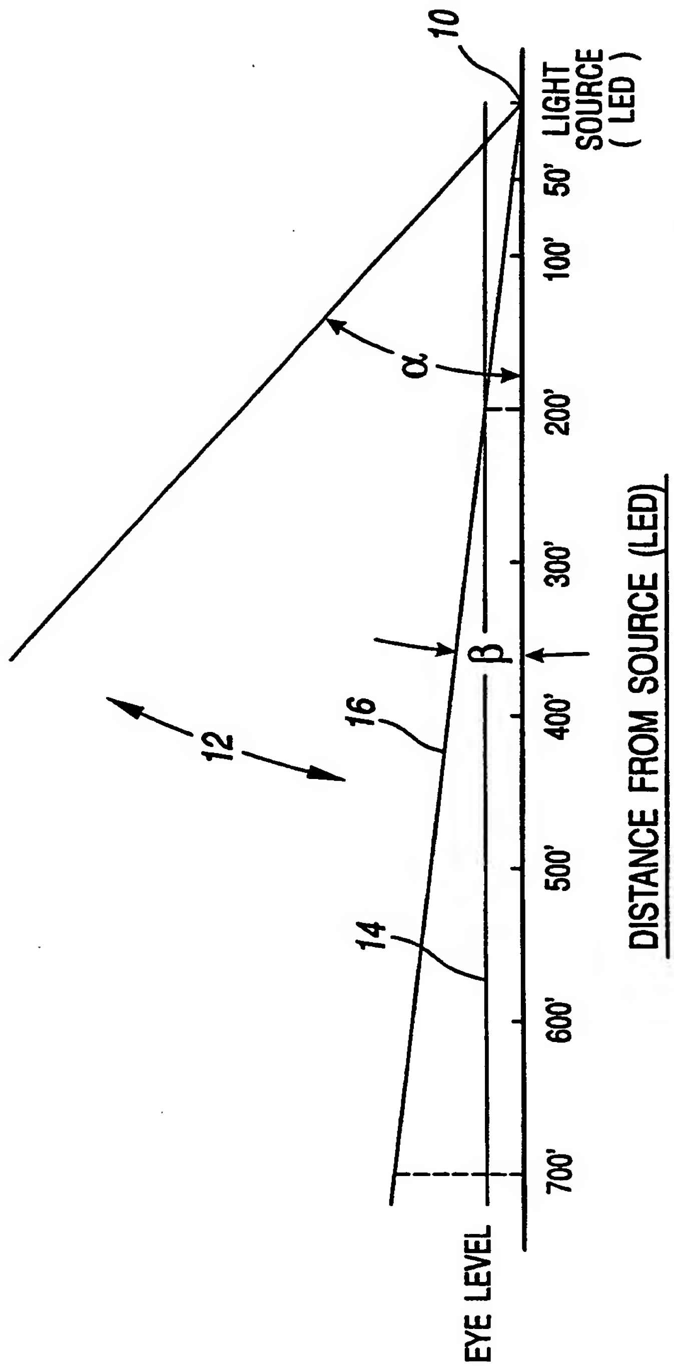
10
LIGHT SOURCE (LED)
50'
100'
200'
300'
400'
500'
600'
700'
α
β
12
16
14
EYE LEVEL
DISTANCE FROM SOURCE (LED)

FIG. 18

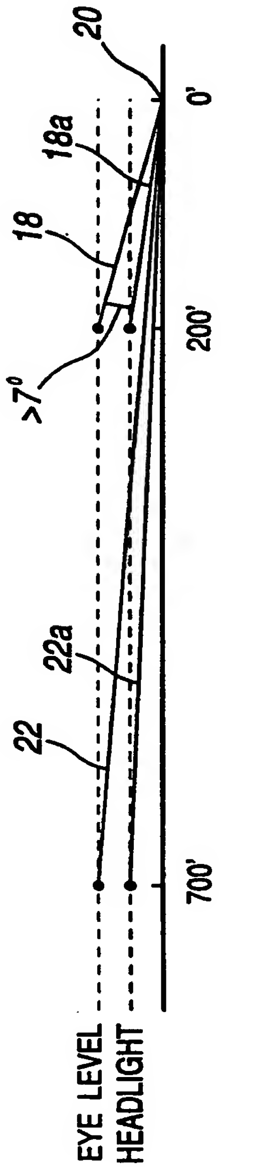
20
0'
18a
18
200'
>7°
22a
22
700'
EYE LEVEL
HEADLIGHT

FIG. 19

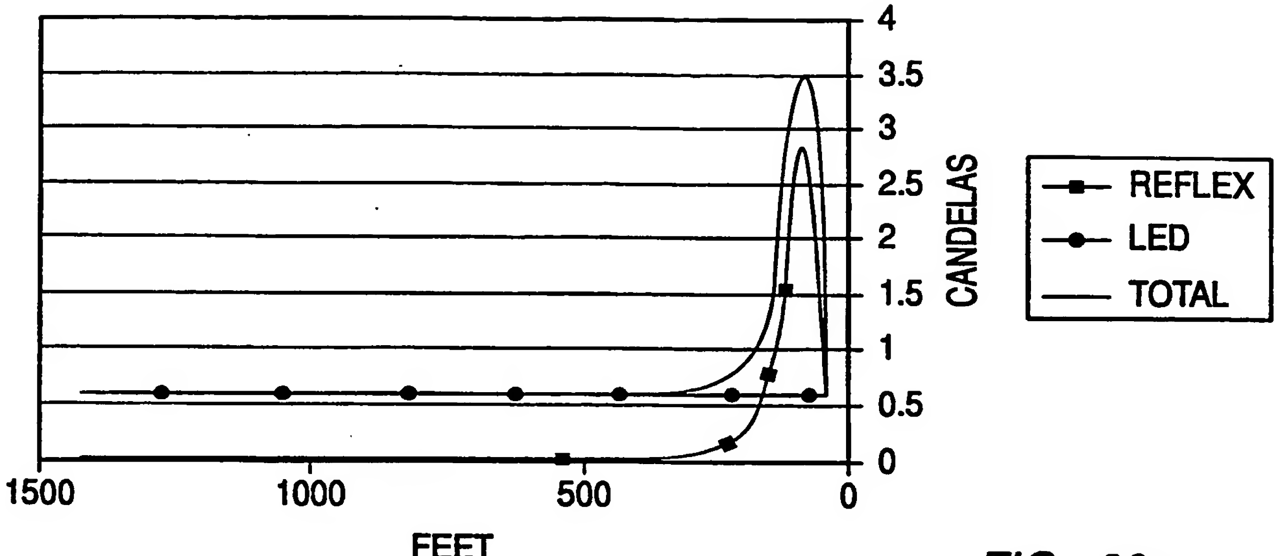

FIG. 20a

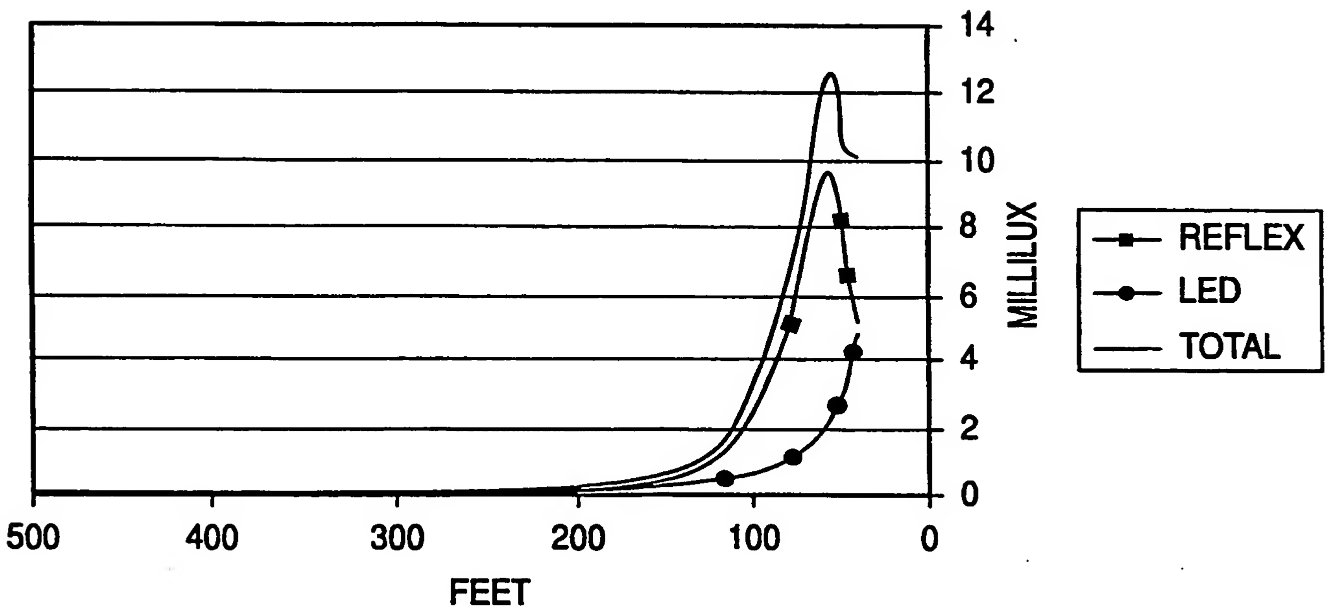

FIG. 20b

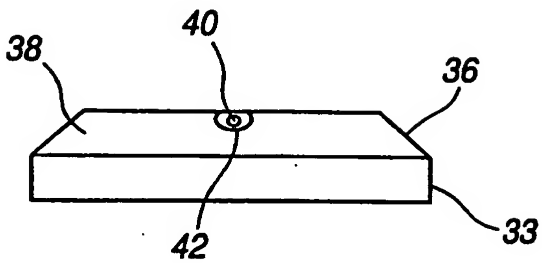

FIG. 21

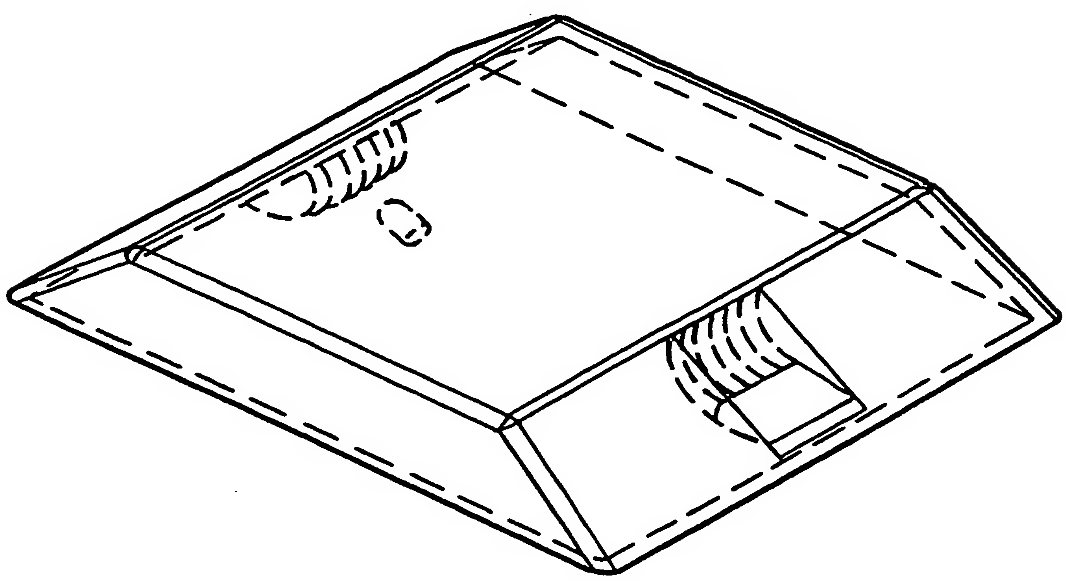

FIG. 21a

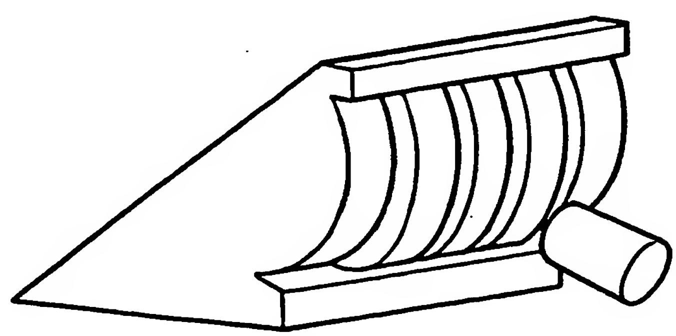

FIG. 21b

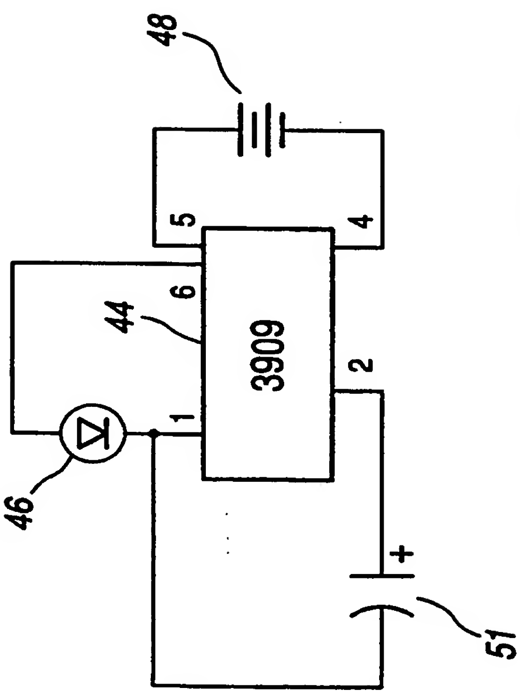

FIG. 22

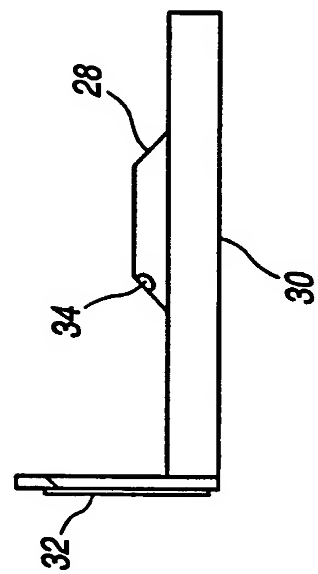

FIG. 23

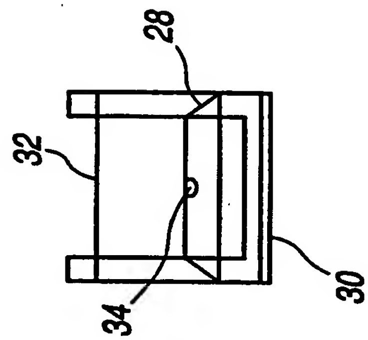

FIG. 24

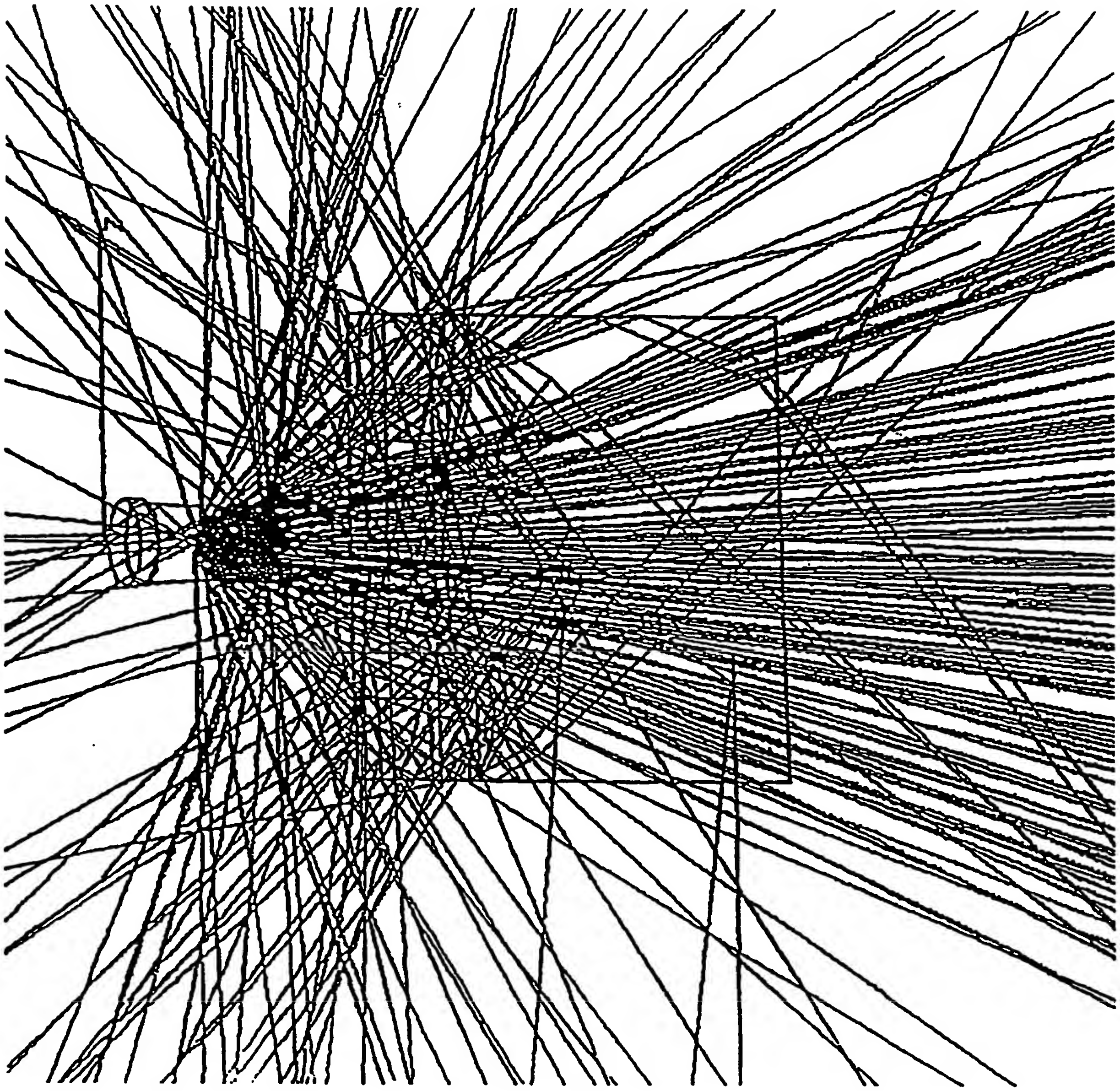

FIG. 25

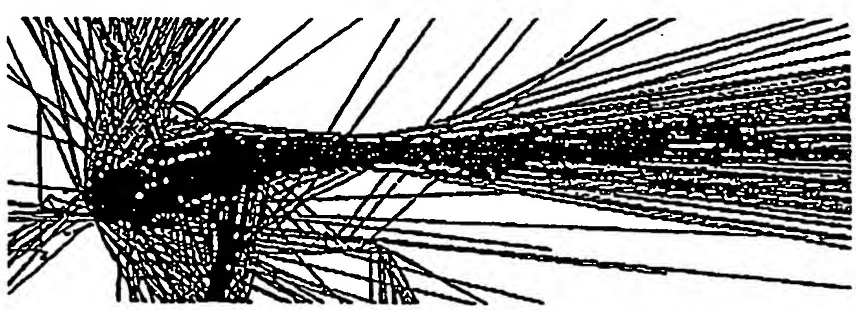

FIG. 26

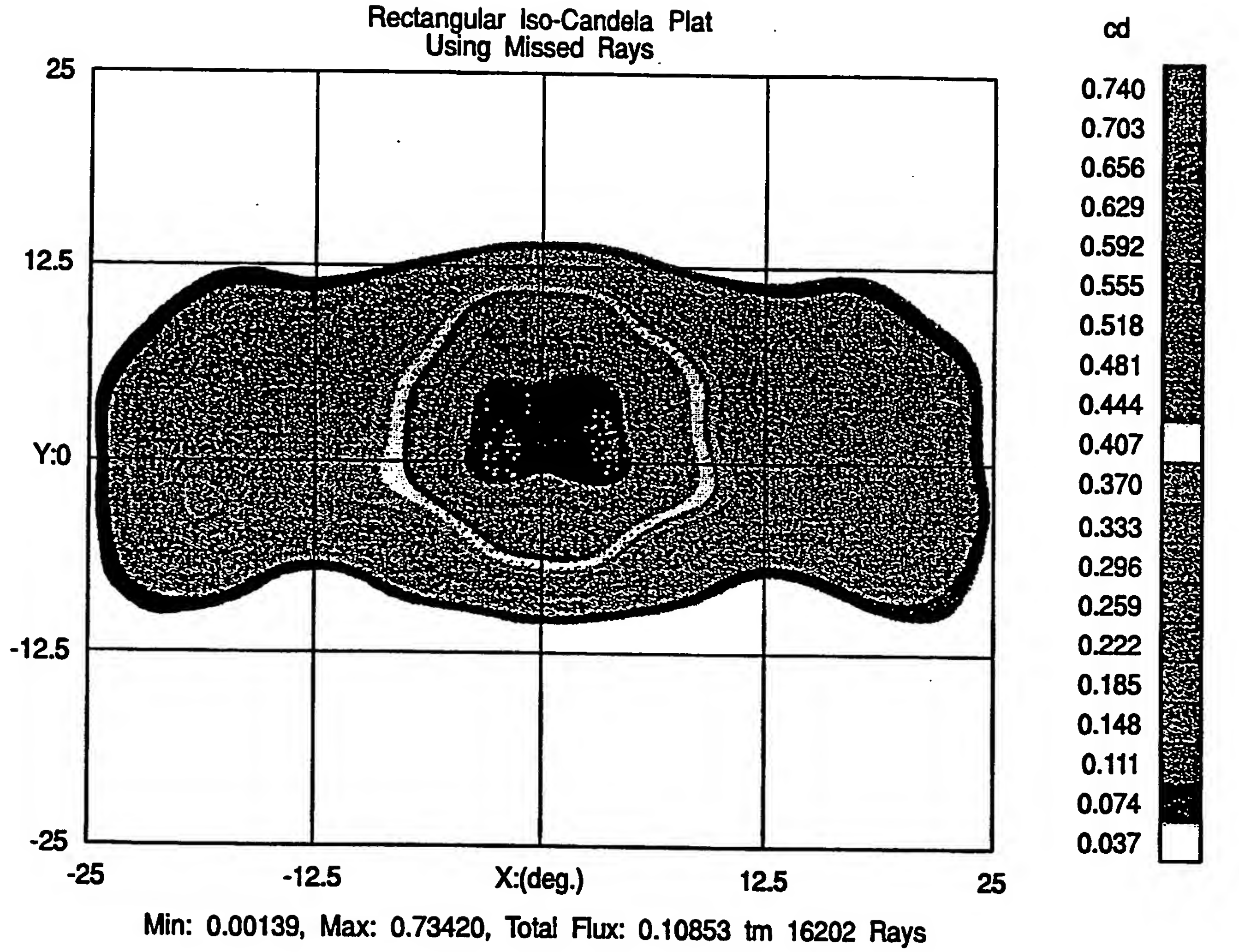
Rectangular Iso-Candela Plat
Using Missed Rays
cd
0.740
0.703
0.656
0.629
0.592
0.555
0.518
0.481
0.444
0.407
0.370
0.333
0.296
0.259
0.222
0.185
0.148
0.111
0.074
0.037
25
12.5
Y:0
-12.5
-25
-25
-12.5
X:(deg.)
12.5
25
Min: 0.00139, Max: 0.73420, Total Flux: 0.10853 tm 16202 Rays

FIG. 27

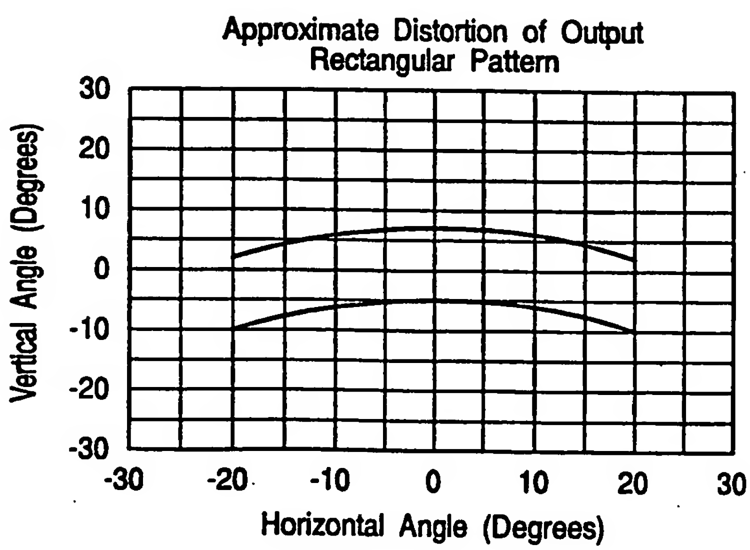
Approximate Distortion of Output
Rectangular Pattern
Vertical Angle (Degrees)
30
20
10
0
-10
-20
-30
-30
-20
-10
0
10
20
30
Horizontal Angle (Degrees)

FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/10755

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) :G02B 6/00
US CL :385/147; 404/12-16
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : GO2B 6/00; EO1F 9/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
SEARCHED EAST; search terms: (pavement$ adj marker$) and (led adj focus$)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,668,120 A (ROBERTS) 26 MAY 1987 (26/05/87) (NOTE ENTIRE REFERENCE)	1-64
A	US 4,050,834 A (LEE) 27 SEPTEMBER 1977 (27/09/77)(NOTE ENTIRE REFERENCE)	1-64

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"B" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
18 JULY 2000	25 AUG 2000

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